Lecture Module - Electrical Signals

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Module 4 - Electrical Signals

Module 4 - **Electrical Signals**

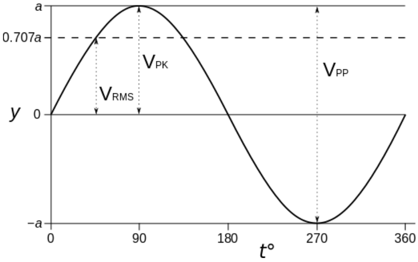
- Topic 1 - Classification of Signals
- Topic 2 - Signal Analysis
- Topic 3 - Sampling and Aliasing

Topic 1 - Classification of Signals

- Introduction to Signal Concepts
- Analog, Discrete, or Digital
- Static or Dynamic
- Deterministic or Non-Deterministic

Introduction to Signal Concepts

Signal, Amplitude, and Frequency



The shape and form of a signal are often referred to as its waveform. The waveform contains information about the magnitude and amplitude, which indicate the size of the input quantity, and the frequency, which indicates the way the signal changes in time.

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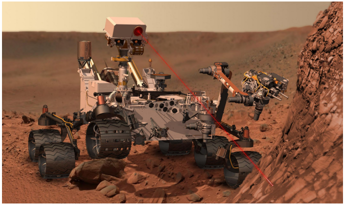
Introduction to Signal Concepts

A signal is the physical information about a measured variable being transmitted between a process and the measurement system, between the stages of a measurement system, or as the output from a measurement system.


Images: Wikipedia

Analog, Discrete, or Digital

- **Analog Signal- magnitude is continuous in time**
- **Discrete Time Signal- magnitude at points in time**

  - sampling at repeated time intervals
- **Digital Signal- exists in discrete points in time**

  - magnitude is also discrete

Analog, Discrete, or Digital

Analog describes a signal that is continuous in time. Because physical variables tend to be continuous, an analog signal provides a ready representation of their time-dependent behavior.

Examples: voltage in a circuit

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...a discrete time signal, for which information about the magnitude of the signal is available only at discrete points in time. A discrete time signal usually results from the sampling of a continuous variable at repeated finite time intervals.

Examples:

A digital signal has two important characteristics. First, a digital signal exists at discrete values in time, like a discrete time signal. Second, the magnitude of a digital signal is discrete, determined by a process known as quantization at each discrete point in time.

Examples:

Static or Dynamic

Signals may be characterized as either static or dynamic. A static signal does not vary with time.

A dynamic signal is defined as a time-dependent signal. In general, dynamic signal waveforms, $y(t)$, may be classified as shown in Table 2.1.

Static or Dynamic

Deterministic or Non-Deterministic

A deterministic signal varies in time in a predictable manner, such as a sine wave, a step function, or a ramp function, as shown in Figure 2.5. A signal is steady periodic if the variation of the magnitude of the signal repeats at regular intervals in time. Also described in Figure 2.5 is a non-deterministic signal that has no discernible pattern of repetition. A non-deterministic signal cannot be prescribed before it occurs, although certain characteristics of the signal may be known in advance.

Deterministic or Non-Deterministic

Table 2.1 Classification of Waveforms

I.	Static	$y(t) = A_0$
II.	Dynamic	
	Periodic waveforms	
	Simple periodic waveform	$y(t) = A_0 + C\sin(\omega t + \phi)$
	Complex periodic waveform	$y(t) = A_0 + \sum_{n=1}^{\infty} C_n \sin(n\omega t + \phi_n)$
	Aperiodic waveforms	
	Step[a]	$y(t) = A_0 U(t)$ $= A_0$ for $t > 0$
	Ramp	$y(t) = A_0 t$ for $0 < t < t_f$
	Pulse[b]	$y(t) = A_0 U(t) - A_0 U(t - t_1)$
III.	Nondeterministic waveform	$y(t) \approx A_0 + \sum_{n=1}^{\infty} C_n \sin(n\omega t + \phi_n)$

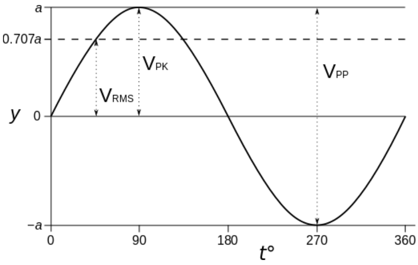
[a] $U(t)$ represents the unit step function, which is zero for $t < 0$ and 1 for $t \geq 0$.
[b] t_1 represents the pulse width.

Table 2.1 : Theory and Design for Mechanical Measurements

Topic 2 - Signal Analysis

- Signal Mean Value
- Power Dissipation
- Signal Root Mean Square (RMS) Value
- Discrete-Time or Digital Signals

Signal Mean Value



Mean Value

$$\bar{y} \equiv \frac{\int_{t_1}^{t_2} y(t)dt}{\int_{t_1}^{t_2} dt}$$

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Signal Mean Value

Dissipation - Time Rate of Energy Dissipation

$$P = I^2 R$$

Total Electrical Energy

$$E = \int_{t_1}^{t_2} P dt = \int_{t_1}^{t_2} [I(t)]^2 R dt$$

Power Dissipation

- For a cyclically alternating electric current, RMS is equal to the value of the direct current that would produce the same average power dissipation in a resistive load.
- In Estimation theory, the root mean square error of an estimator is a measure of the imperfection of the fit of the estimator to the data.
- The RMS value of a signal having a zero mean is a statistical measure of the magnitude of the fluctuations in the signal.

Signal Root Mean Square (RMS) Value

$$(I_e)^2 R(t_2 - t_1) = \int_{t_1}^{t_2} [I(t)]^2 R dt$$

$$I_e = \sqrt{\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} [I(t)]^2 dt}$$

$$y_{rms} = \sqrt{\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} [y]^2 dt}$$

Signal Root Mean Square (RMS) Value

$$\bar{y} = \frac{1}{N}\sum_{i=0}^{N-1} y_i$$

$$y_{RMS} = \sqrt{\frac{1}{N}\sum_{i=0}^{N-1} y_i^2}$$

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Signal Root Mean Square (RMS) Value

Table 2.1 : Theory and Design for Mechanical Measurements

Discrete-Time or Digital Signals

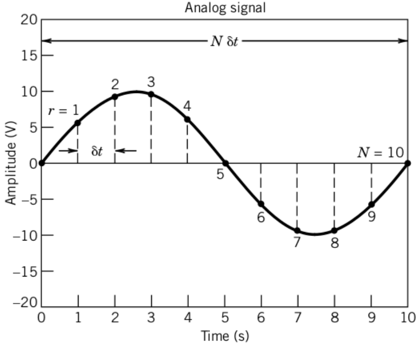
Discrete-Time or Digital Signals

Topic 3 - Sampling and Aliasing

- Sampling
- The Aliasing Phenomenon
- Example by Hand
- MATLAB Example

Sampling

… A discrete time signal usually results from the sampling of a continuous variable at repeated finite time intervals. …



Discrete time signal

$\{y(r\delta t)\}$

r	Discrete data
0	0
1	5.9
2	9.5
3	9.5
4	5.9
5	0
6	–5.9
7	–9.5
8	–9.5
9	–5.9
10	0

Text,Figure: Theory and Design for Mechanical Measurements Ch. 7

The Aliasing Phenomenon

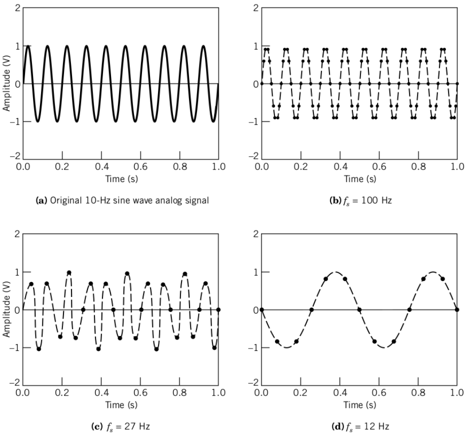


Figure: Theory and Design for Mechanical Measurements Ch. 7

Example by Hand

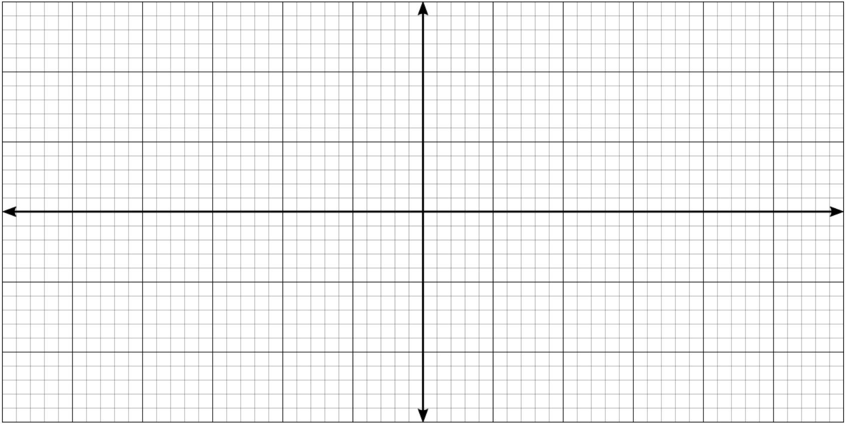


Image: T.Hill

Example by Hand

MATLAB Example

Activity: Sampling Demonstration

Use the MATLAB program provided to accomplish the following:

1. Plot a sinusoidal signal $y(t) = Asin(\omega \cdot t) = Asin(2\pi f \cdot t)$ with an amplitude $A = 10$ (units) and frequency $f = 1000$ (Hz). This is the *ideal signal* source.
   - Include axis labels and gridlines.
   - Choose amplitude and time scales so that 15 to 20 periods or the waveform are shown.
2. Simulate the samping of the signal by plotting the same function with a reduced time step. Plot the sampled signal on the same figure. Use a different marker and include a legend to differentiate the signals.
3. Use your code to determine the minimum sampling frequency required to measure the following quantities (note: use the sampled signal only, the *ideal signal* is not accessible).
   - Frequency of the *ideal signal*
   - Amplitude of the *ideal signal*

Deliverables: Submit answers to all questsions to the appropriate ilearn folder. If you work with a partner, include all names with the responses. All group members must submit the assignment.

MATLAB Example